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The SeaWiFS Aerosol Product Compared to Coastal and Island *In Situ* Measurements

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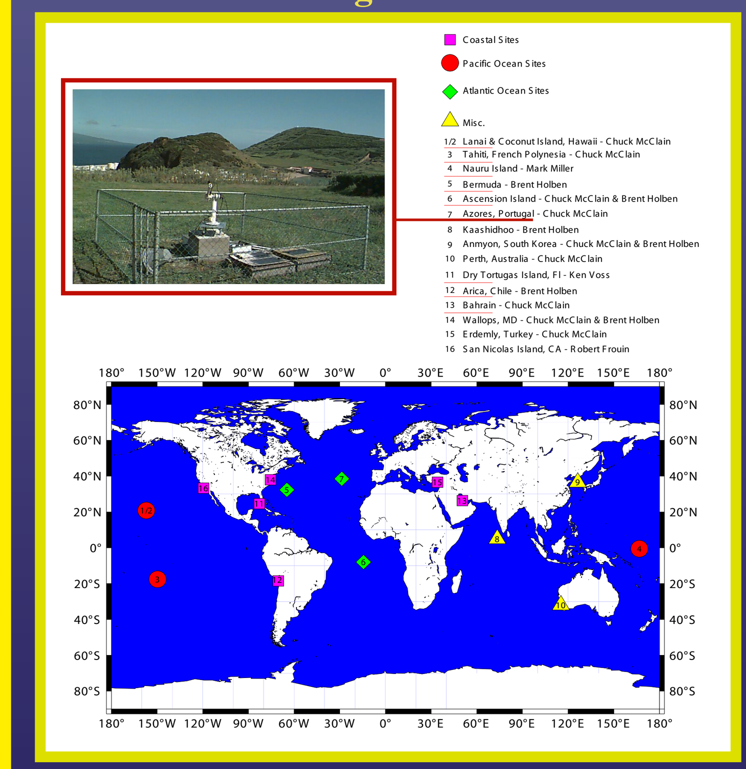
ABSTRACT

The Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS, http://simbios.gsfc.nasa.gov) Project is assisting the ocean color community to cross calibrate and merge data products from multiple ocean color missions. The atmospheric contribution plays an essential role in the analysis of the ocean color imagery. The correction of the atmospheric contribution is a crucial procedure that requires *in situ* measurements of atmospheric and bio-optical components to compare and validate satellite measurements. The SIMBIOS Project is using *in situ* atmospheric data for several purposes, including validation of SeaWiFS and other ocean color mission's aerosol optical products, evaluation of the aerosol models currently used for atmospheric correction, and development of vicarious sensor calibration methodologies. The principal source of *in situ* aerosol observations is the Aerosol Robotic Network (AERONET) that provides globally distributed, near-real time, observations of spectral aerosol optical depths, aerosol size distributions and precipitable water. Since 1997, the SIMBIOS Project has augmented the AERONET network with 13 additional island and coastal sites, including the Hawaiian Islands (Lanai and Oahu), Ascension Island, Bahrain, Tahiti, Wallops Island (US East Coast), South Korea, Turkey, Argentina, Azores, and Australia and more recently Morocco. The AERONET and SIMBIOS Projects have invested considerable effort to deploy and maintain the instruments to ensure the quality of the data for more than 4 years. Match-ups between aerosol optical thickness obtained for various sites from *in situ* and satellite-derived observations are presented and discussed. Match-up analysis methods and uncertainties are also discussed.

In situ data collected and downloaded from CIMEL Stations

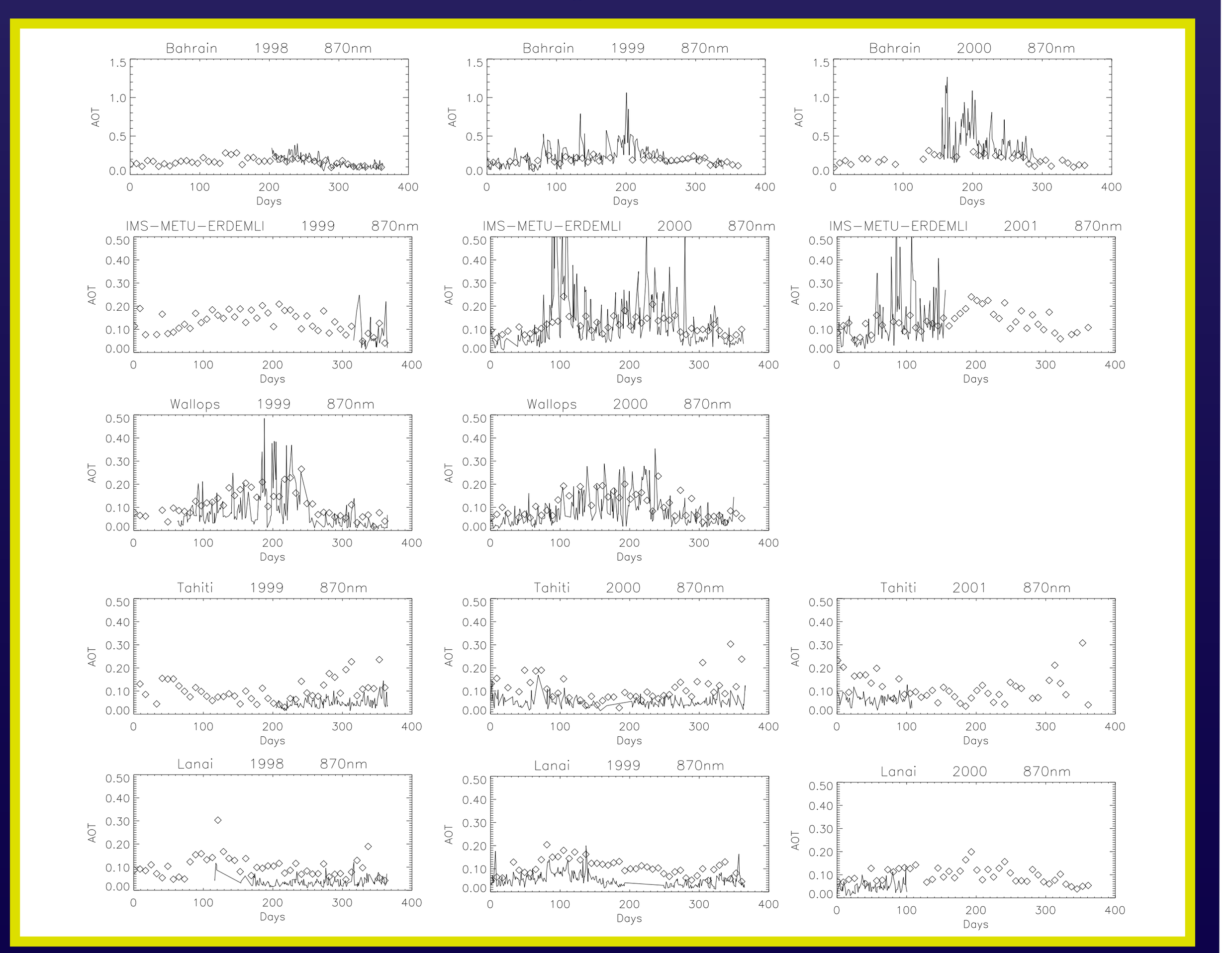
Figure 1



The principal source of *in situ* aerosol observations is AERONET, a network of ground based automated sun photometers owned by national agencies and universities (Holben et al, 1998, 2000).
AERONET data provides globally distributed, near real time observations of aerosol optical depths, aerosol size distributions, and precipitable water (http://aeronet.gsfc.nasa.gov). The SIMBIOS Project augmented AERONET with 13 additional island and coastal sites. Figure 1 shows the AERONET and SIMBIOS sites used for matchup analysis. Analysis has been completed for sites that are underlined in red. The other sites are currently being processed and will be used in the future. Chinae (South Korea), Puerto Madryn (Argentina) and Dahkla (Morocco) are three SIMBIOS sites that were not used for this analysis because of a lack of available data.
The SIMBIOS Project also has several hand-held MicroTops sun photometers, ship-stabilized PREDE sun photometers, and SIMBAD/SIMBADA radiometers. Measurements collected onboard ship with these instruments and the corresponding SeaWiFS matchups are presented in the poster #A51B-07.

In situ - *SeaWIFS* AOT Time Series

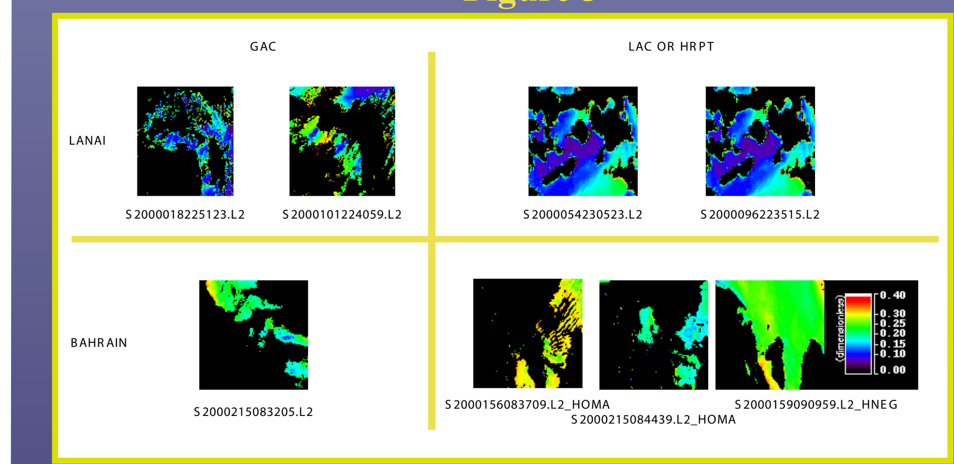
Figure 2



Before looking at matchups between *in situ* and SeaWiFS data, the AOT time series was produced for some specific sites. Figure 2 shows the time series since 1997, for three coastal sites (Wallops - Eastern US, Erdemli - Turkey and Bahrain - Gulf) and two Islands (Tahiti - South Pacific, and Lanai - North Pacific).
The diamonds represent the SeaWiFS 8-day composites at 865nm (from cloud screened, 9x9 pixel, level 3 globally binned product) and the solid line corresponds to the CIMEL level 2.0 daily average (Quality Controlled Product). (Smirnov, et al. 2000)
The long term trend is well retrieved by SeaWiFS in most sites. Because of the low AOT measured over Tahiti, an overestimation by SeaWiFS occurred at that site. Of course, the uncertainty of the retrieval by both *in situ* and SeaWiFS instruments is higher for low AOT measurements.

Global Match-up Results Since 1997

Figure 3



In situ data are compared to satellite image files by matching the two data sources in time and space. The SeaWiFS Project's HDF file database is queried for files that spatially and temporally match a record in the *in situ* data source. A region encompassing 101 by 101 pixels centered on the matched pixel is extracted from the selected level-1A files (GAC, LAC or HRPT, shown in Figure 3). Each L1A match is processed to a level-2 (L2) product containing all $\tau_a(\lambda)$ and ancillary data (ozone, wind speed, and atmospheric pressure). The final valid matches are determined after applying a number of exclusion criteria that remove invalid or redundant data from consideration. The exclusion criteria are:
- a time window of +/-180 min between *in situ* records and satellite overpass time,
- pixels excluded because of applied flags, such as atmospheric correction failure, land, sun glint, total radiance above the knee, high satellite zenith angle, stray light, clouds or ice, sensor stray light, or low Lwn(555).

The match-up approach uses a 21x21 pixel box for LAC resolution data and a 5x5 pixel box for GAC data to keep a nearly equivalent area extent. Further refinements are then considered to account for the number of valid pixels in the box, the multiple SeaWiFS files per matchup, the multiple *in situ* records, and the case of extreme variation between pixels which represents frontal regions or anomalies.
More details regarding the satellite aerosol optical thickness match-up procedures are described in Bailey and Wang, 2001 and Wang et al, 2000.

Figure 4

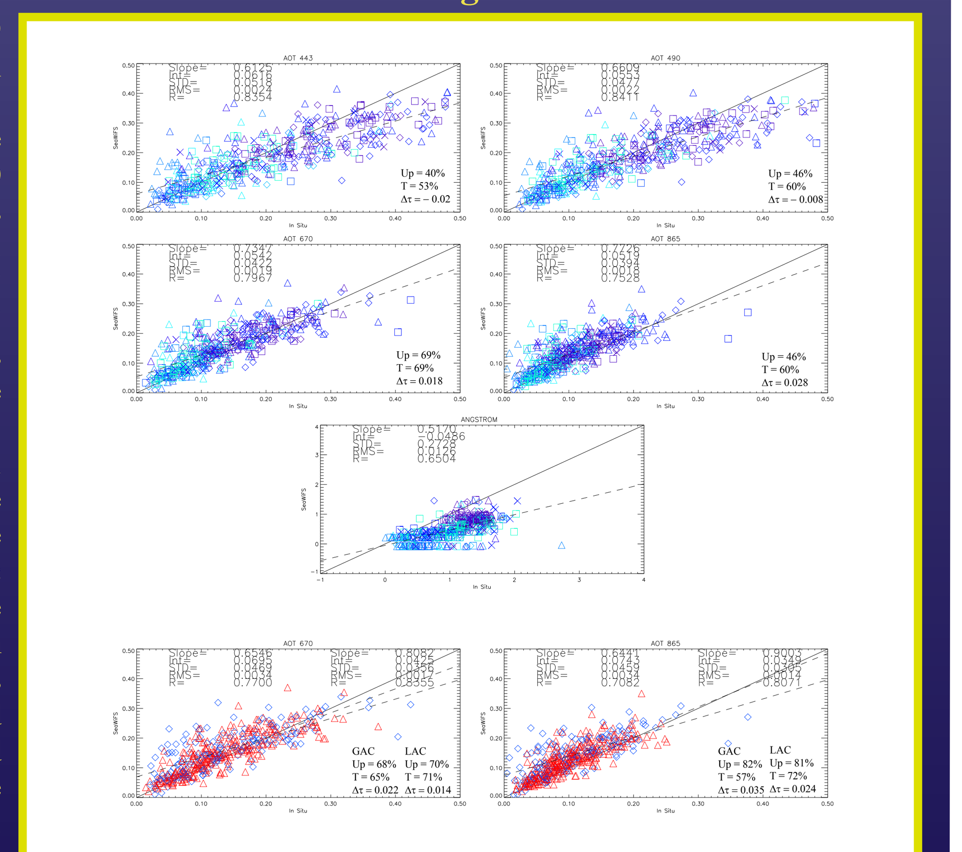


Figure 4 shows the *In situ* - *SeaWiFS* matchups obtained for the 9 considered sites (see Fig. 1). Almost 500 Matchups were obtained, all bands combined, since 1997. The straight lines correspond to the 1:1 line and the dotted lines are the corresponding linear fit. The top five plots represent the AOT matchups at four wavelengths (443, 490, 670 and 865 nm) and the Angstrom Exponent. Each symbol corresponds to one year since 1997, and each color corresponds to one site. Several parameters are displayed on the bottom of each plot: "Up" represents the percentage of matchups over the 1:1 line. "T" represents the percentage of matchup for which the AOT difference is lower than 0.04 and "$\Delta\tau$" is the average differencs between the SeaWiFS-derived AOT and *in situ* AOT.
The AOT matchups compare well in the near-infrared bands, however, SeaWiFS overestimates AOT at 865nm. The slope of the linear fit decreases toward the visible spectrum, showing that the SeaWiFS algorithm underestimates AOT measurements relative to *in situ* observations. Both the aerosol model and the AOT value retrieved by SeaWiFS depend on the relative and absolute calibration of the near-infrared bands. Generally, the Angstrom Exponent is underestimated by SeaWiFS. In most cases the SeaWiFS-derived Angstrom Exponent is not higher than 1 whereas *in situ*-derived Angstrom Exponent is often between 1 and 2. The two plots on the bottom represent the SeaWIFS-*In situ* matchups at 670 and 865 nm. SeaWiFS GAC data are shown as blue diamonds, while LAC data are shown as red triangles. The result is slightly improved if only LAC data are considered, probably because the SeaWiFS instrument stray light is corrected better. No signifigant improvements were found for the Angstrom Exponent comparison.
Similar studies are presented in this session using photometric measurements made onboard ships in the open ocean with hand-held sun photometers and fast-rotating shadowband radiometers (see AGU poster - A51B-07).

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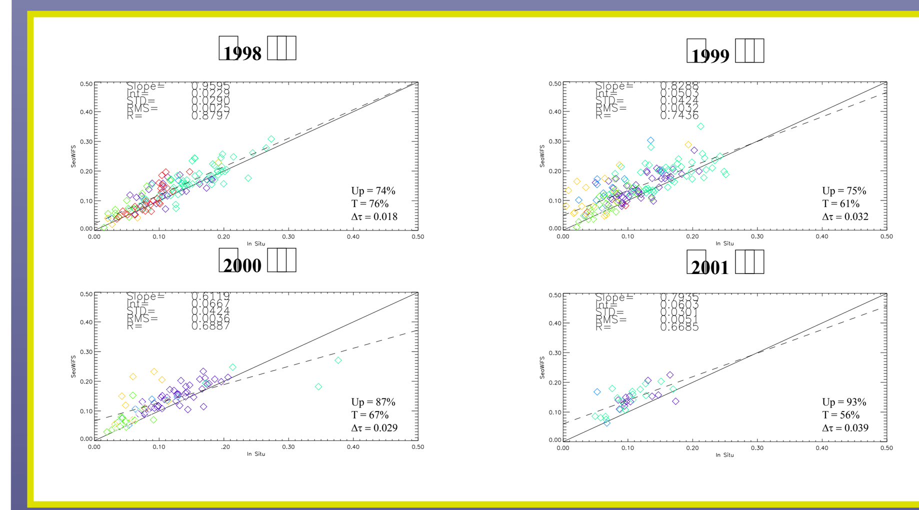
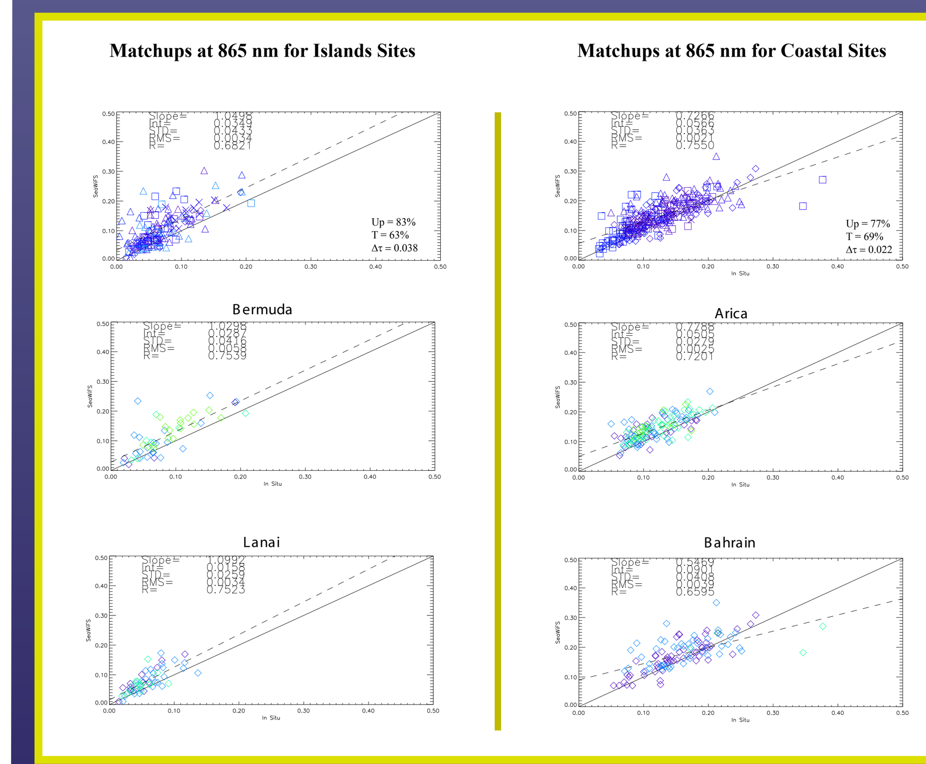
Figure 5



Yearly Matchups at 865 nm

Figure 5 shows matchups for all sites, by year, since 1997 at 865 nm (SeaWiFS band 8). 129 matchups were obtained in 1998, 172 in 1999, and 140 in 2000. Only 32 matchups are obtained in 2001 because some of the 9 selected sites did not collect data in 2001. The data collected by the 7 other sites are currently being processed and will hopefully increase the number of matchups in 2001. The AOT retrieved by SeaWiFS is always higher than the *in situ* AOT. The overestimation is more significant each year. The correlation coefficient varies from 0.88 in 1998 to 0.67 in 2001. The matchup are also more scattered year after year, as the RMS value increases from 0.25% in 1998 to 0.51% in 2001. The average differences increase over the year from 0.018 to 0.039 because island sites dominate in 2000 and 2001. More coastal measurements are being processed and should slightly balance the result.

Figure 6



Geographical Matchups at 865 nm

Coastal and island matchups obtained at 865nm since 1997 are shown in Figure 6. 300 total matchups were retrieved. The AOT range is wider for coastal sites, and the average match-up differences are higher for the island sites (0.038) than the coastal sites (0.022). The 170 island matchups rarely show AOT's lower than 0.1, and there is a systematic bias between *in situ* and SeaWiFS measurements. However, the slope is close to 1.

Accuracy of the matchups

The accuracy assessment needs to take into account the uncertainties of the CIMEL sun photometers and the satellite sensor as well as the statistical validity of the AOT match-up set. The uncertainty of the CIMEL sun photometer is estimated by Holben et al, 1998 at +/-0.015. The SeaWiFS aerosol optical thickness is obtained as a simple extension of the atmospheric correction algorithm and the uncertainty of the derived AOT value is estimated to be lower than 10% (Gordon et al, 1994), +/-0.02 is generally admitted. The error bars were not added to maintain the clarity of each plot. If the *in situ* and SeaWiFS AOT differ by 0.04, the matchup could be considered good.

Discussion and Conclusion

Match-up analyses between aerosol optical thickness derived from SeaWiFS sensor and *in situ* sun photometers were conducted. A previous match-up study (Ainsworth et al, 2001) showed that 85% of near infrared AOT's were overestimated by SeaWiFS. In this study, 80% of cases were overestimated at 865nm. The overestimation averages 0.028 at 865nm for all sites, 0.022 for the coastal sites, and 0.038 for island sites. *In situ* measurements collected since 1997 by CIMEL sun photometers and managed by the AERONET program were used to match with the derived SeaWiFS AOT product. 16 sites were considered for the matchups and partial results from 9 sites are presented in this poster. The cloud screened, quality controlled level 2.0 AOT was selected and reduced to a time window within +/-180min of the SeaWiFS overpass. The SeaWiFS AOT obtained as a simple extension of the atmospheric correction of the algorithm is selected after applying a number of exclusion criteria. The *in situ* measurements were compared to the SeaWiFS data, and the final matches were presented at four SeaWiFS wavelengths. The matchups were presented for each year since 1997, considering only island or coastal sites.

The main results :
- A slight overestimation in the near infrared bands (0.028 on average at 865nm) and an underestimation at shorter wavelengths are consistently retrieved in all sites.
- The overestimation is more significant for the island sites (0.038) than for the coastal sites (0.022).
- The SeaWiFS Angstrom Exponent range is between -0.08 and 1.48, while the *in situ* Angstrom Exponent is often 2. Thus the Angstrom Exponent is frequently underestimated by SeaWiFS.
- The underestimation at shorter wavelengths is primarily due to the model selection by SeaWiFS based on the spectral dependence in relatively narrow region of the NIR spectrum. Liberti et al, 2001 has shown similar results over the Mediterranean sea. Both the aerosol model selected by SeaWiFS and the AOT value retrieved by SeaWiFS depend on the relative and absolute calibration of the NIR bands that need also to be explored.

The future analysis will focus on:
- analyzing the 7 other sites that are located primarily in coastal region and check the magnitude of the overestimation at 865nm with the current results,
- analyzing the match-up time series for the linear fit, the average differences and the other parameters.